

Chooz, Palo Verde, Krasnoyarsk

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This is a short review of the present ~ 1 km baseline oscillation experiments at nuclear reactors. An idea of a new search for very small mixing angle oscillations at Krasnoyarsk is also mentioned.

1. INTRODUCTION

In this report we discuss the following topics:

- The CHOOZ experiment (France, Italy, Russia, USA): final results based on the entire data sample [1]. We refer to the previous publication [2] for CHOOZ'97 results and the general description of the experiment.
- The Palo Verde experiment (Caltech, Stanford, Alabama, Arizona): first results [3].
- The Krasnoyarsk underground (600 mwe) site: a possible two detector experiment "Kr2Det" to search for very small mixing angles in the atmospheric mass parameter region [4].

Other experiments at Krasnoyarsk are presented at this Conference by Yu. Kozlov. All oscillation experiments are based on the reaction $\bar{\nu}_e + p \rightarrow e^+ + n$, and use e^+, n delayed coincidence technique. The first two of them make use of Gd loaded liquid scintillator, for Krasnoyarsk no Gd doping is planned.

2. THE CHOOZ EXPERIMENT

The CHOOZ detector used a 5 ton target (Fig.1). It was located in an underground laboratory (300 mwe) at a distance of about 1 km from two PWR type reactors of total (nominal) power 8.5 GW(th).

A summary of the data taking from April 1997 and July 1998 is shown in the Table 1.

To identify the $\bar{\nu}_e$ absorption in the target the following selection criteria were used: (i) a time delay between the e^+ and the neutron: 2 - 100 μ s; (ii) spatial conditions: distance from PMT surface of e^+ and neutron candidates $d > 0.3$ m, distance between e^+ and $n < 1$ m; (iii) energy window for n candidates (6 - 12) MeV, and for e^+ candidates $\sim (1.3 - 8)$ MeV. Under these conditions the $\bar{\nu}_e$ detection efficiency was found to be $\epsilon = (69.8 \pm 1.1)\%$

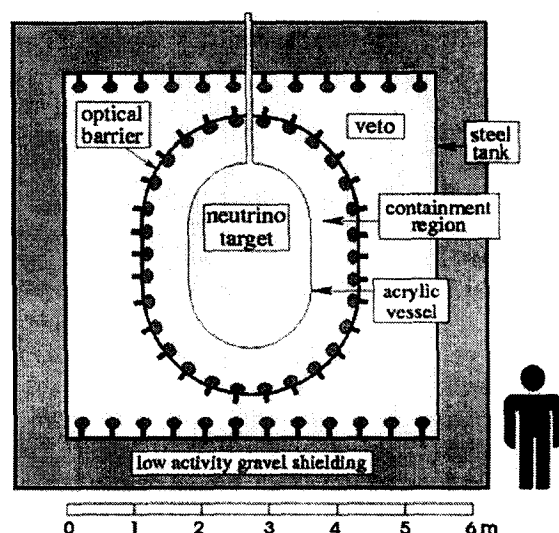


Figure 1. The CHOOZ detector.

A total about 2500 neutrino events were detected during the data acquisition periods. The measured neutrino detection rate is 2.5 ($d^{-1}GW^{-1}$), the neutrino detection rate to

Table 1
Data taking cycles at CHOOZ:

	Time (d)	\bar{W} (GW)
Reactor 1 ON, Reactor 2 OFF	85.7	4.03
Reactor 2 ON, Reactor 1 OFF	49.5	3.48
Reactors 1 and 2 ON	64.3	5.72
Reactors 1 and 2 OFF	142.5	

background ratio is 10:1 (typically). The measured positron energy spectrum is in good agreement with the expected spectrum in a no-oscillation case (Fig.2). The neutrino detection rates ratio $R_{meas/calc}$ of measured to calculated for no oscillation is found to be:

$$R_{meas/calc} = 1.01 \pm 2.8\%(stat) + 2.7\%(syst)$$

The components of the combined systematic error are listed in the Tab. 2.

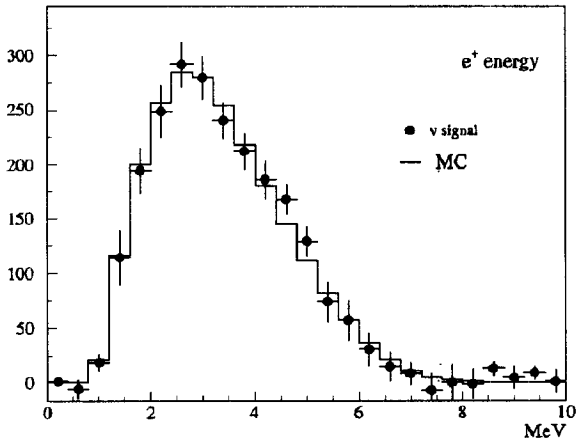


Figure 2. CHOOZ'99 positron spectrum (dots). The solid line is calculated no-oscillation positron spectrum.

The CHOOZ'99 oscillation limits are derived by comparing all the experimental information available to expected no-oscillation values and directly depend on the correct determination of the absolute value of the $\bar{\nu}_e$ flux, their energy spectrum, the nuclear fuel burn up effects and on other issues listed in Table 2.

It can be seen (Fig.3) that new oscillation constraints are two times more stringent than those of the CHOOZ'97. We note also that CHOOZ experiment does NOT observe $\bar{\nu}_e$ oscillations in the mass region Δm_{atm}^2 where muon neutrinos oscillate intensively [5].

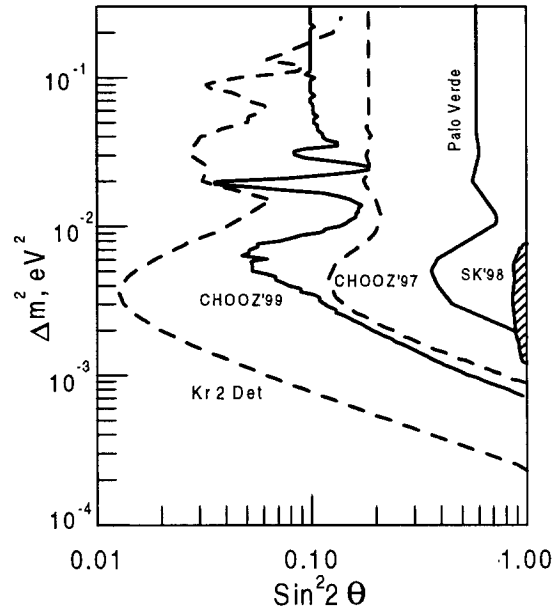


Figure 3. Reactor oscillation parameter plots. “CHOOZ'97”, “CHOOZ'99”, “Palo Verde” and “Kr2Det” are 90% CL $\bar{\nu}_e$ disappearance limits; “SK'98” is the allowed $\bar{\nu}_\mu$ oscillation region.

3. THE PALO VERDE EXPERIMENT

The detector is a matrix of 6×11 acrylic cells each 9 m long filled with liquid scintillator (12

Table 2

Systematic uncertainties in CHOOZ'99

parameter	error
reaction cross section	1.9%
number of protons	0.8%
detection efficiency	1.5%
reactor power	0.7%
combined	2.7%

tons total weight). The detector is installed in an underground (32 mwe) laboratory at a distance of ~ 800 m from three reactors whose total power is 11 GW(th). The signature for $\bar{\nu}_e$ is a fast triple $e^+\gamma\gamma$ coincidence followed by a delayed signal from the neutron. The resultant efficiency of neutrino detection was found to be ca 16%.

Presently (September, 1999) results of the first 72 days of data taking are available. The 3 reactors ON minus 2 reactors ON data give a neutrino detection rate of 6.4 ± 1.4 per day. This number is compatible with expectations for no oscillations. The relevant exclusion plot is shown in Fig.3. The experiment is continuing and a large increase of the sensitivity to the mixing angle is expected.

4. POSSIBLE EXPERIMENT AT KRASNOYARSK

4.1. Contra and pro

- Shall we apply new efforts and search with higher sensitivity for the oscillations of reactor $\bar{\nu}_e$ in the atmospheric neutrino mass region? Often the answer is: - Well, may be not now... After all we know already from CHOOZ that $\bar{\nu}_e$ can contribute no more than 10% to the oscillations of atmospheric neutrinos...

The support comes from theorists [6]: - While atmospheric problems are also important, the reconstruction of the neutrino mixing is one of the most fundamental problems of particle physics. In this particular case the quantity “ $\sin^2 2\theta$ ” is directly expressed through the element U_{e3} of the neutrino mixing matrix: $\sin^2 2\theta = 4U_{e3}^2(1 - U_{e3}^2)$ (U_{e3} is the contribution of the mass-3 state to the electron neutrino state: $\nu_e = U_{e1}\nu_1 + U_{e2}\nu_2 + U_{e3}\nu_3$).

4.2. The idea of the Kr2Det experiment

The practical goal of the Kr2Det is to decrease, relative to the CHOOZ'99, the statistic and systematic errors as much as possible. Therefore we turn to the time honored idea of a near detector and consider two identical liquid scintillation spectrometers (see fig.4.) stationed underground (600 mwe) at 1100 m and 250 m from the reactor. We increase the neutrino target masses up to 50 tons and choose a miniature version of the KamLAND detector design (KamLAND has a 1000 ton target).

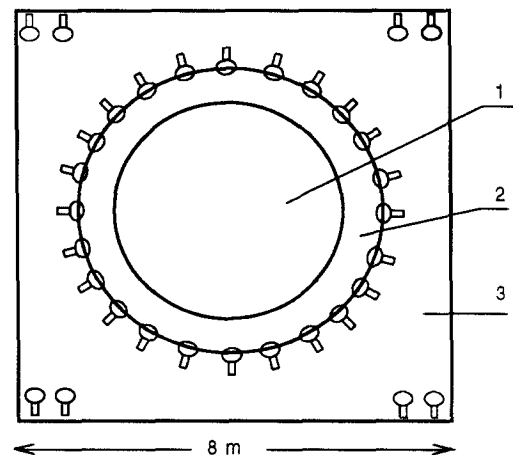


Figure 4. The Kr2Det detector (schematic). 1 - the target, 50 ton mineral oil (PPO), 2 - mineral oil, 3 - veto zone.

In the no-oscillation case the ratio of the two simultaneously measured positron spectra is

Table 3

Expected $\bar{\nu}_e$ detection rates and backgrounds at Kr2Det.

Parameter	Distance (m)	$\bar{\nu}_e$ (d^{-1})	BKG (d^{-1})
Detector 1	1100	50	5
Detector 2	250	900	5

energy independent. Small deviations from the constant value are searched for oscillations. The results are independent of the exact knowledge of $\bar{\nu}_e$ flux and energy spectrum, burn up and reaction cross section, numbers of target protons... However the difference of the detector energy scales (response functions) should be controlled. By special intercalibration procedures we plan to monitor the difference and to introduce necessary corrections.

Expected 90% CL oscillation limits are shown in Fig.3. It was assumed that 40 000 $\bar{\nu}_e$ are detected in the detector at 1100m and that the detector response ratio is controlled down to 0.5%.

5. CONCLUSIONS

The one km baseline experiments at reactors, CHOOZ and Palo Verde, have successfully reached the atmospheric neutrino mass region and have explored there a large area on oscillation parameters plane.

With the Kr2Det experiment this area can be considerably expanded towards small mixing angles and new information on the neutrino intrinsic properties obtained. We note also that the Kr2Det project is relatively inexpensive when compared to typical experiment of the OSCILLATION INDUSTRY list.

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